Suggested area: Electronic Devices

High Reliability of 0.1 μm InGaAs/InAlAs/InP HEMT MMICs on 3 " InP Substrate

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Abstract

High-reliability performance of K-band MMIC amplifiers fabricated using 3" 0.1 μm production InGaAs/InAlAs/InP HEMT process technology is reported. Operating at an accelerated life test condition of Vds=1.5V and Ids=150mA/mm, two-stage balanced amplifiers were lifetested at two-temperatures (T_1=230°C, and T_2=250°C) in the N_2 ambient. The activation energy (Ea) is as high as 1.4 eV, achieving a projected median-time-to-failure (MTF) > $1x10^6$ hours at a 125°C junction temperature. MTF was determined by 2T constant current stress using $|\Delta S21| > 1.0$ dB as the failure criteria. This is the first report of 0.1 μm InGaAs/InAlAs/InP HEMT high reliability based on small-signal microwave characteristics of HEMT MMIC. This result demonstrates a robust InGaAs/InAlAs/InP HEMT production technology.

Summary

We have developed a highly robust 0.1 μm InP HEMT MMIC technology that has demonstrated excellent millimeter wave performance to meet the strong demand of present and future commercial and military electronic systems (1,2). With InP HEMT becoming a preferred technology for system performance improvement or the next generation system design, the demonstration of a reliable technology for providing high performance MMICs at low cost and high yield to both the space/defense and commercial markets is essential. However, while the published data of InP HEMT reliability has been mostly focused on discrete devices (3,4), few investigated the lifetest at the MMIC level which allows the reliability assessment on InP HEMT devices, passive element, metal and interconnect, and via hole integrity. The result from this investigation benefits the microwave and wireless communities by demonstrating a reliable and robust InP HEMT technology, a critical factor in widespread acceptance of InP HEMTs for next generation applications.

The cross section of an InP HEMT is shown in Fig. 1. Figure 2 shows the typical 0.1 μm Gmp versus Vgs on a 3" InP substrate, indicating a uniform process. The historical data shows a tight Gmp distribution with average Gmp of 970 mS/mm and standard deviation of 46 mS/mm. A two-stage K-band (27-40 GHz) balanced MMIC amplifier was used for reliability evaluation as shown in Fig. 3. Amplifiers were biased @ Vds=1.5 V, Ids=150mA/mm with varying ambient temperature from 150°C to 250°C for the step stress to determine the suitable temperature for 2T lifetest. S21 degrades drastically as $T_{ambient}$ rises up to 250°C. From step stress, $T_{ambient}$ =230°C, and 250°C were chosen for the 2T lifetest. During the lifetest, $|\Delta S21| > 1.0$ dB @ 35 GHz was measured for the failure criteria as shown in Fig.4. S21 change is primarily dictated by the Gm change (Fig.4). Reliability data analysis shows that degradation is mainly due to the channel carrier degradation instead of gate metal sinking observed in GaAs HEMT.

The lifetest failure distribution is plotted on a log-normal scale in Fig.5. Fig.6 is an Arrhenius life-temperature model based on the median-time-to-failure at each lifetest temperature. The Arrhenius model projects a MTF > $1x10^6$ hours at a 125°C junction temperature with an Ea>1.4 eV. This is the state-of-art of reliability results on 0.1 μm InP HEMT MMIC amplifiers stressed at high Tj in the N_2 ambient.

References

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2. R. Lai et al., the Technical Digest of IPRM, 1997.
3. A.S. Wakita et al., the Technical Digest of IPRM, 1997.
4. K. Van Der Randen, IEEE Trans Electron Devices, vol. 46, No.8, 1999.

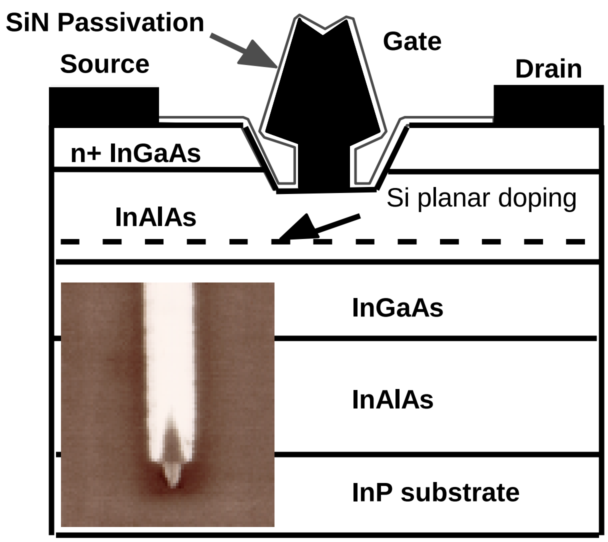

Fig. 1: Cross section of an InAlAs/InGaAs/InP HEMT (Insert: 0.1 μm T-gate).

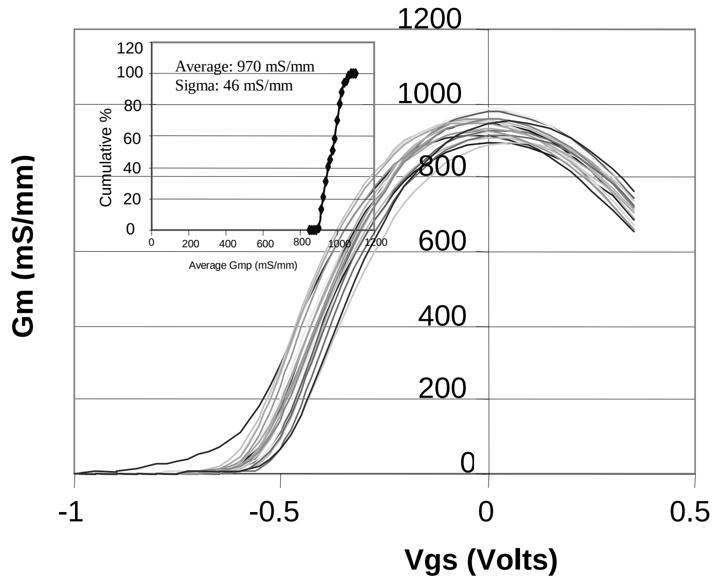

Fig.2: Uniform Gm-Vgs distribution on 3” InP substrate (Insert:Gmp Histogram with average Gmp of 970 mS/mm; sigma: 46 mS/mm)

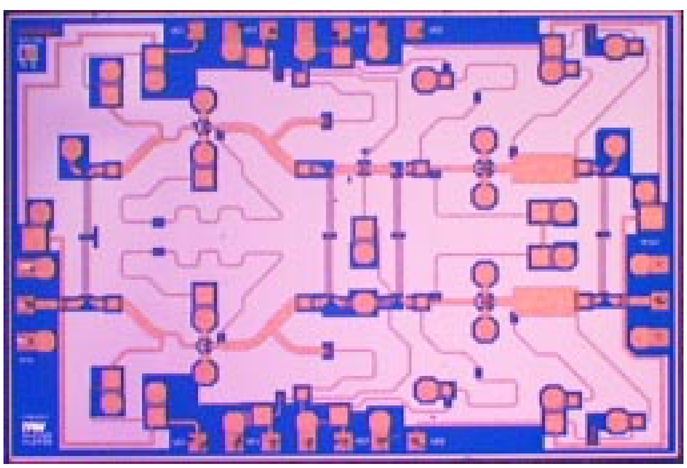

Fig.3: Micrograph of a K- band balanced MMIC amplifier, operating over 27-40 GHz.

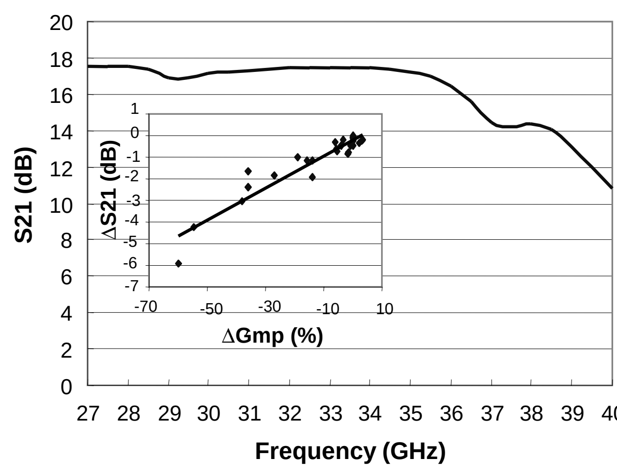

Fig.4: Room temperature S21 characteristics of a K-band Balanced amplifier (Insert: ΔS21 versus ΔGmp)

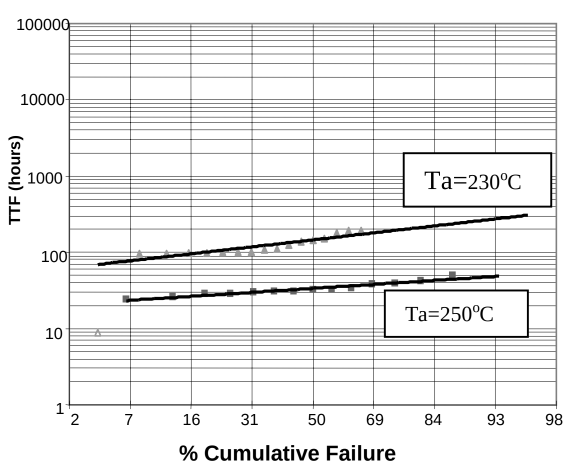

Fig.5: Log normal distribution for 2T lifetest @ $T_{ambient}$=230°C, and 250°C.

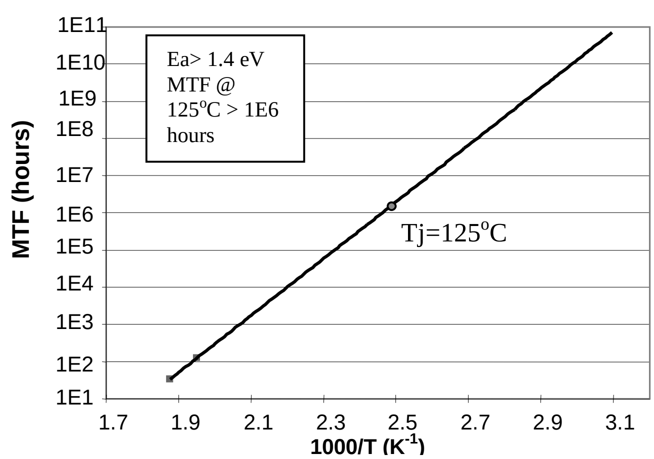

Fig.6: Arrhenius plot of 0.1 μm InP HEMT MMIC amplifiers.

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